US009182309B2

(12) **United States Patent**
**Hirata et al.**

(10) **Patent No.: US 9,182,309 B2**
(45) **Date of Patent: Nov. 10, 2015**

(54) **KNOCKING SENSOR**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 378 days.

(21) Appl. No.: **13/583,944**

(22) PCT Filed: **Feb. 24, 2011**

(86) PCT No.: **PCT/JP2011/001056**
§ 371 (c)(1),
(2), (4) Date: **Sep. 11, 2012**

(87) PCT Pub. No.: **WO2012/114380**
PCT Pub. Date: **Aug. 30, 2012**

(65) **Prior Publication Data**
US 2013/0000387 A1 Jan. 3, 2013

(51) **Int. Cl.**
***G01L 23/22*** (2006.01)
***G01L 19/06*** (2006.01)
***G01L 19/14*** (2006.01)

(52) **U.S. Cl.**
CPC ........... ***G01L 23/222*** (2013.01); ***G01L 19/0681*** (2013.01); ***G01L 19/141*** (2013.01)

(58) **Field of Classification Search**
CPC ..................................................... G01L 23/222
USPC ......................................................... 73/35.11
See application file for complete search history.

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(57) **ABSTRACT**

There is provided a knocking sensor that has good insulation characteristics even at an operating temperature of 150° C. or more and is excellent in the accuracy of knocking detection. The knocking sensor **10** includes a sensor body **20** including: a metal shell **12** that includes a cylindrical portion **12***a* and a flange portion **12***b* positioned at one end of the cylindrical portion **12***a* and protruding outward in a radial direction; an annular piezoelectric element **15**; upper and lower electrode plates **16** and **14** that are superimposed on upper and lower surfaces of the piezoelectric element **15**; a weight **17** that is disposed so that the piezoelectric element **15** is interposed between the weight and the flange portion **12***b*; a lower insulating plate **13** that is disposed between the flange portion **12***b* and the lower electrode plate **14**; and an upper insulating plate **13***t* that is disposed between the upper electrode plate **16** and the weight **17**; and a resin molding **11** that covers the sensor body **20**. Further, the thickness of each of the upper and lower insulating plates **16** and **14** is in the range of 0.05 mm to 0.50 mm, and the resin molding **11** is made of polyphenylene sulfide having good heat resistance.

**1 Claim, 6 Drawing Sheets**

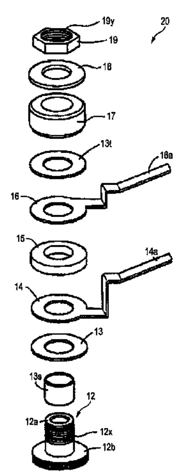

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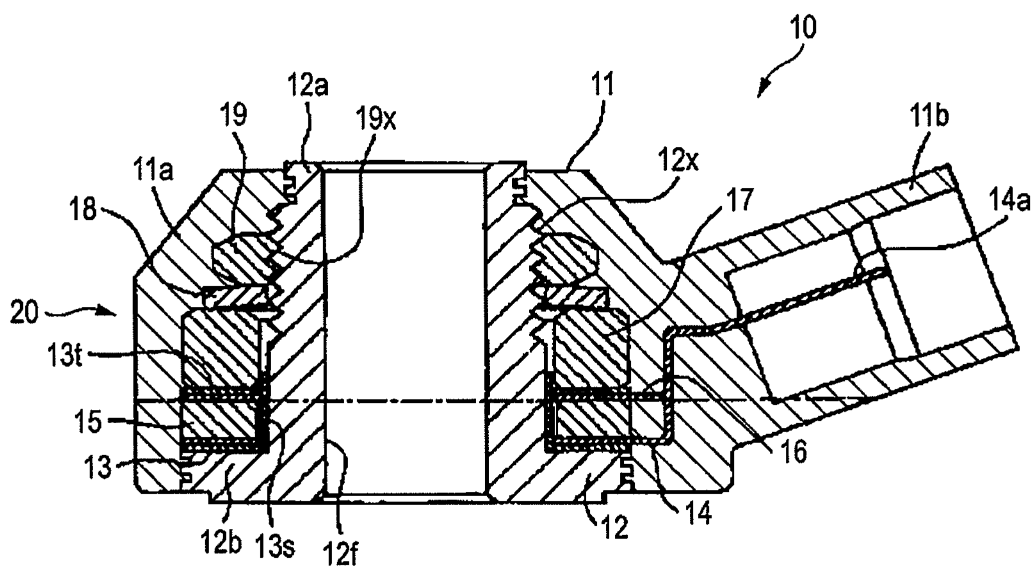
FIG. 1


10
12a
11
19
19x
11b
12x
11a
14a
18
17
20
13t
15
16
13
14
12
12b
13s
12f

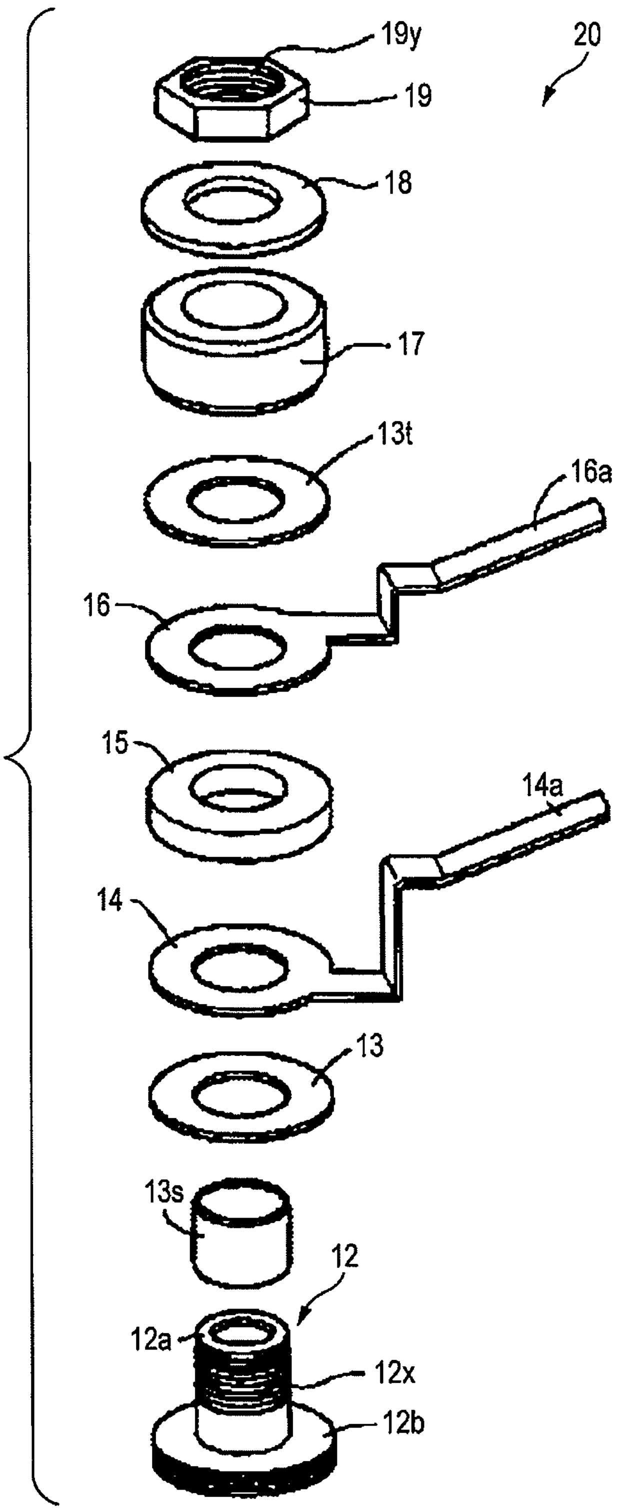
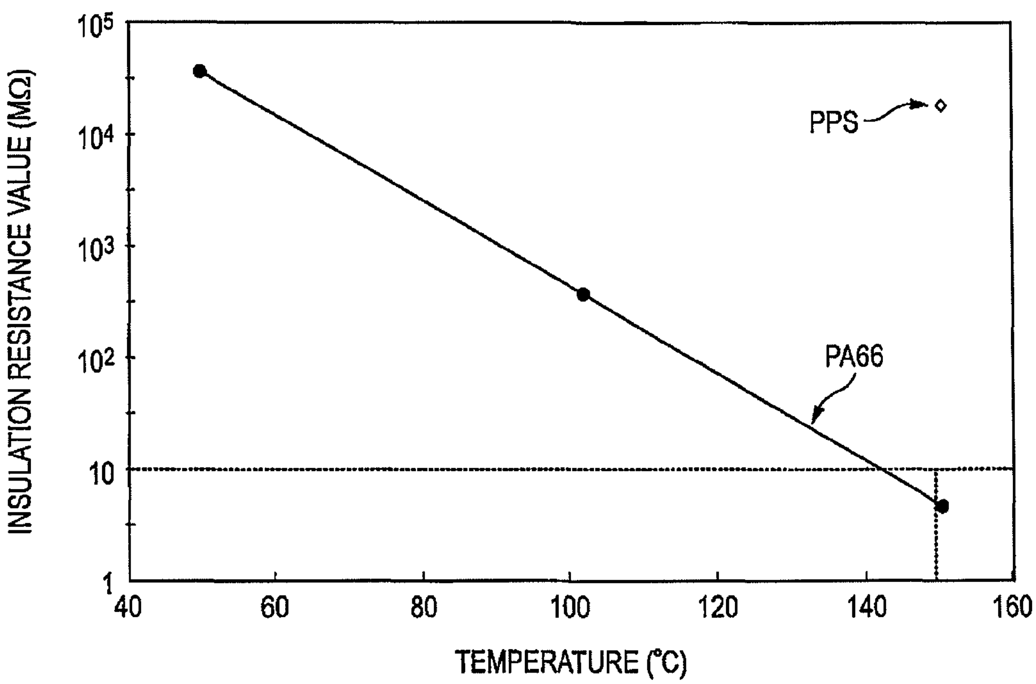


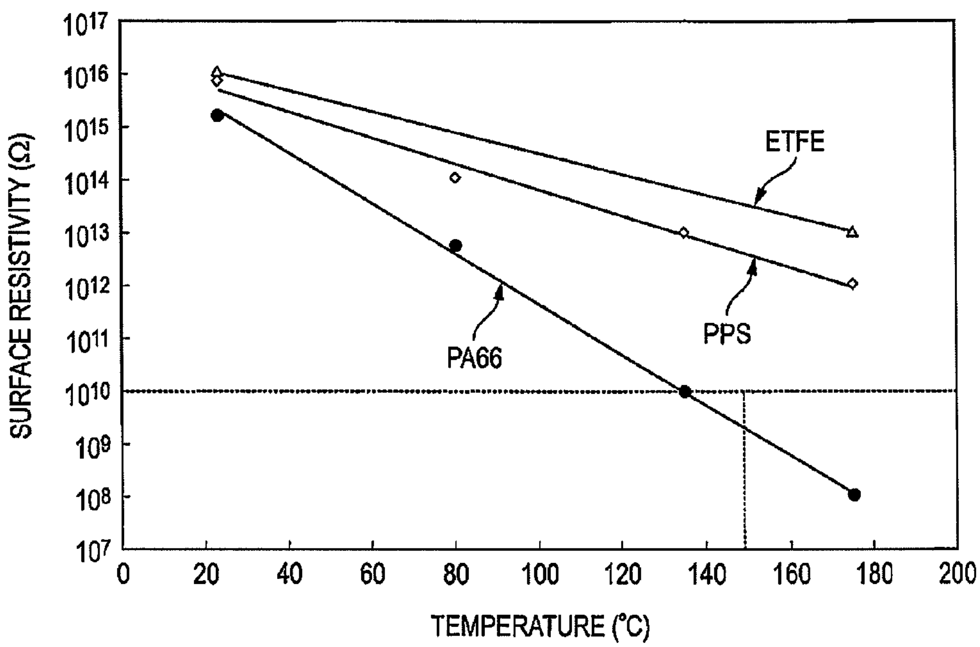

FIG. 2

FIG. 3



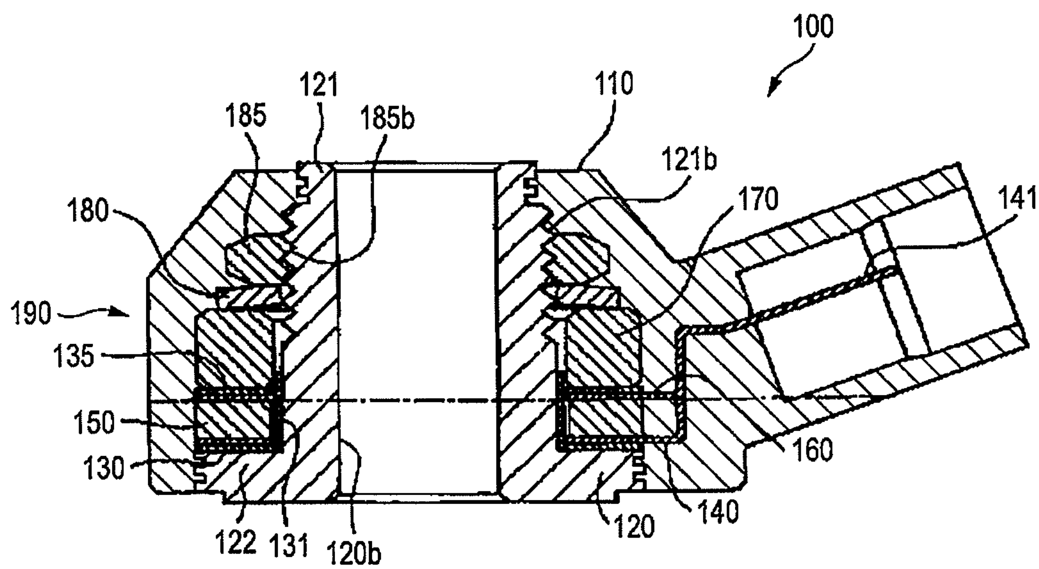
INSULATION RESISTANCE VALUE (MΩ)
$10^5$
$10^4$
$10^3$
$10^2$
10
1
40
60
80
100
120
140
160
TEMPERATURE (℃)
PPS
PA66

FIG. 4



10^17
10^16
10^15
10^14
10^13
10^12
10^11
10^10
10^9
10^8
10^7
SURFACE RESISTIVITY (Ω)
ETFE
PPS
PA66
0
20
40
60
80
100
120
140
160
180
200
TEMPERATURE (°C)

FIG. 5


100
121
110
185
185b
121b
180
170
141
190
135
150
130
160
140
120
122
131
120b

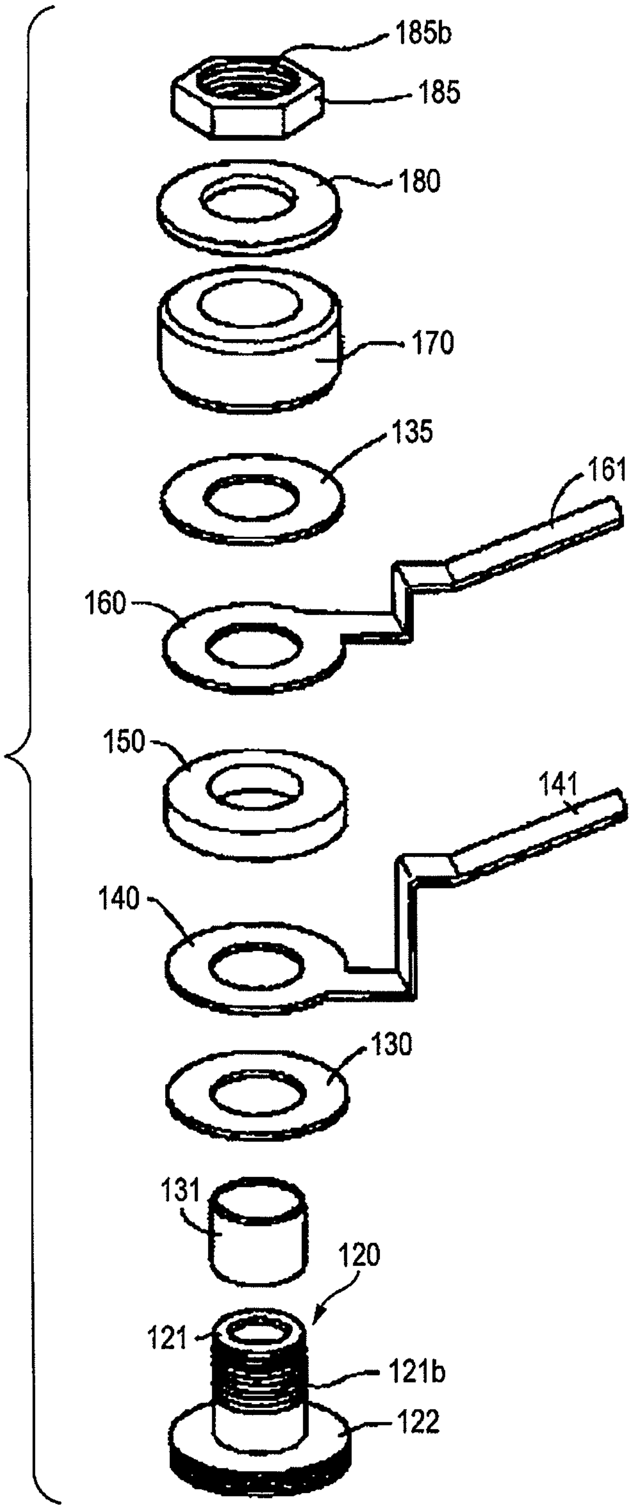

185b
185
180
170
135
161
160
150
141
140
130
131
120
121
121b
122

FIG. 6

# KNOCKING SENSOR

## TECHNICAL FIELD

The present invention relates to a knocking sensor that uses a piezoelectric element.

## BACKGROUND ART

A knocking sensor, which detects the knocking of an internal combustion engine of an automobile or the like, is known and the delay control of an ignition timing of a spark plug is performed according to the detection of the knocking sensor.

A knocking sensor, which has a structure shown in FIGS. **5** and **6**, is known as the above-mentioned knocking sensor (Patent Documents 1 and 2). The knocking sensor **100** is a so-called center hole-type non-resonant knocking sensor that has a mounting hole **120***b*, through which the knocking sensor is mounted on a cylinder block of an internal combustion engine, at the central portion thereof.

As shown in an exploded perspective view of FIG. **6**, the knocking sensor **100** includes a metal shell **120** that includes a cylindrical portion **121** and a flange portion **122** positioned at the lower end of the cylindrical portion **121**. An annular lower insulating plate **130**, a lower electrode plate **140**, a piezoelectric element **150**, an upper electrode plate **160**, an upper insulating plate **135**, a weight **170**, and a disc spring **180** are fitted to the outer periphery of the cylindrical portion **121** in this order from the flange portion **122**. Meanwhile, upper and lower terminals **141** and **161**, which are used to take a voltage, are formed on the outsides of the lower and upper electrodes **140** and **160**, respectively, so as to extend in the shape of a piece in the radial direction. A male screw portion **121***b* is formed on the upper outer peripheral surface of the cylindrical portion **121**. Meanwhile, a female screw portion **185***b* is formed on the inner surface of a nut **185**. Further, the nut **185** is threadably engaged with the male screw portion **121***b*. Accordingly, a laminated body, which reaches the disc spring **180** from the lower insulating plate **130**, is interposed between the flange portion **122** and the nut **185**, so that a sensor body **190** is formed (see FIG. **5**). Furthermore, the sensor body **190** is covered with a resin molding **110** as shown in FIG. **5**, so that the knocking sensor **100** is formed.

When being used, the knocking sensor **100** having this structure is mounted so that the lower surface of the flange portion **122** of the metal shell **120** comes into contact with the cylinder block. Accordingly, the metal shell **120** is electrically connected to (comes into electrical contact with) the cylinder block. As a result, the weight **170**, which is electrically connected to the metal shell **120**, is also electrically connected to (also comes into electrical contact with) the cylinder block. Accordingly, the lower insulating plate **130** that electrically insulates the flange portion **122** of the metal shell **120** from the lower electrode plate **140** and the upper insulating plate **135** that electrically insulates the upper electrode plate **160** from the weight **170** are used in the knocking sensor **100** as components of the sensor body **190** so that the insulation between the piezoelectric element **150** and the metal shell **120** and the weight **170** is secured. Meanwhile, a cylindrical insulating sleeve **131** is fitted to the outer peripheral surface of the cylindrical portion **121**, so that the lower electrode plate **140**, the piezoelectric element **150**, and the upper electrode plate **160** are prevented from being electrically connected to the cylindrical portion **121**.

[Patent Document 1] JP-A-2003-322580
[Patent Document 2] JP-A-2008-144677



## SUMMARY OF INVENTION

### Problem that the Invention is to Solve

A polyamide resin such as nylon is generally used as the material of the resin molding of the above-mentioned knocking sensor, so that the operating temperature of the knocking sensor becomes about 130° C. Meanwhile, in recent years, a tendency to operate an engine at a high temperature is increased in order to improve the fuel efficiency of an engine. For this reason, the operating temperature of the knocking sensor is also required to be 150° C. or more.

Meanwhile, there is a problem in that the insulation resistance of a knocking sensor in the related art is reduced at a high temperature of 150° C. or more. Here, from the examination of the inventors, it was ascertained that the insulation resistance of a knocking sensor is determined by the surface resistance of the resin molding **110** and the thicknesses (that is, volume resistance) of the lower insulating plate **130** and the upper insulating plate **135**. That is, at least one of the thickness direction of the lower insulating plate **130** (the insulating plate **130** itself) and the inner surface of the resin molding **110** (the surface of the resin molding **110** coming into contact with the lower insulating plate **130**) becomes a conduction path between the flange portion **122** of the metal shell **120** and the lower electrode plate **140**, so that a phenomenon where the insulation resistance of the knocking sensor **100** is reduced due to a temperature rise occurs. Further, at least one of the thickness direction of the upper insulating plate **135** (the upper insulating plate **135** itself) and the inner surface of the resin molding **110** (the surface of the resin molding **110** coming into contact with the upper insulating plate **135**) becomes a conduction path between the upper electrode plate **160** and the weight **170**, so that the above-mentioned phenomenon occurs. Meanwhile, since the resin molding **110** is thick, not the thickness direction of the resin molding but the surface of the resin molding becomes a conduction path and surface resistance becomes an object that determines the insulation characteristics.

Here, since the lower and upper insulating plates **130** and **135** are easily worked, there is room to adjust the thicknesses of the lower and upper insulating plates and select the materials of the lower and upper insulating plates. Accordingly, the volume resistances of these insulating plates **130** and **135** themselves tend to be easily increased. However, since the resin molding **110** requires moldability and there is a restriction on the size of the knocking sensor, the material of the resin molding should be selected and the size of the resin molding should be set in consideration of this. For this reason, it is not easy to increase the surface resistance of the resin molding **110**. Accordingly, in order to increase the insulation resistance of the knocking sensor as a whole and to allow the knocking sensor to be used at a high temperature of 150° C., it is important to increase the surface resistance of the resin molding **110** by increasing the surface resistivity of the resin molding **110** itself under high temperature.

Further, it is considered that the insulation resistance of the knocking sensor **100** is increased while the deterioration of the surface resistance (surface resistivity) of the resin molding **110** caused by a temperature rise is compensated if the lower and upper insulating plates **130** and **135** are formed thick while a polyamide resin is used as the material of the resin molding **110**. However, there are problems in that the frequency characteristics of the knocking sensor **100** are disturbed and the accuracy of knocking detection deteriorates if the thicknesses of the lower and upper insulating plates **130** and **135** are set to be large.

Accordingly, an object of the invention is to provide a knocking sensor that has good insulation characteristics even at an operating temperature of 150° C. or more and is excellent in the accuracy of knocking detection.

## Means for Solving the Problem

In order to solve the above-mentioned problem, according to an aspect of the invention, there is provided a knocking sensor. The knocking sensor includes a sensor body including: a metal shell that includes a cylindrical portion and a flange portion positioned at one end of the cylindrical portion and protruding outward in a radial direction, an annular piezoelectric element that is fitted to an outer periphery of the cylindrical portion, upper and lower electrode plates that are superimposed on upper and lower surfaces of the piezoelectric element, a weight that is fitted to the outer periphery of the cylindrical portion so that the piezoelectric element is interposed between the weight and the flange portion, a lower insulating plate that is disposed between the flange portion and the lower electrode plate and electrically insulates the flange portion from the lower electrode plate, and an upper insulating plate that is disposed between the upper electrode plate and the weight and electrically insulates the upper electrode plate from the weight, and a resin molding that is made of a resin and covers the sensor body. The thickness of each of the upper and lower insulating plates is in the range of 0.05 mm to 0.50 mm, and the resin molding is made of polyphenylene sulfide or a copolymer of tetrafluoroethylene and ethylene.

According to the knocking sensor of the aspect of the invention, the resin molding covering the sensor body is made of a copolymer of tetrafluoroethylene and ethylene or polyphenylene sulfide that has good moldability and heat resistance. The copolymer of tetrafluoroethylene and ethylene and polyphenylene sulfide have high surface resistivity under room temperature and have a surface resistivity of $1.0\times10^{10}\Omega$ (or $\Omega$/q) or more at 150° C. For this reason, if the resin molding is made of the above-mentioned specific material, it is possible to increase the insulation resistance of the knocking sensor as a whole without excessively increasing the thicknesses of the upper and lower insulating plates even when the knocking sensor is exposed to a high temperature of 150° C. or more.

Further, since the resin molding is made of the above-mentioned specific material in the knocking sensor according to the aspect of the invention, it is not necessary to excessively increase the thicknesses of the upper and lower insulating plates as described above. Accordingly, it is possible to suppress the thicknesses of the upper and lower insulating plates to 0.50 mm or less. Therefore, according to the aspect of the invention, it is possible to obtain a knocking sensor that has a high insulating property without the deterioration of frequency characteristics of the knocking sensor and is excellent in the accuracy of knocking detection. Meanwhile, the thickness of each of the upper and lower insulating plates is 0.05 mm or more. The reason for this is that it is not possible to maintain the insulation resistance of the knocking sensor to be high as a whole if the volume resistances of the insulating plates themselves are reduced even though the surface resistivity of the resin molding itself is increased. Meanwhile, as long as the above-mentioned thickness range is satisfied, a general-purpose resin material (for example, PET) may be used as the material of each of the upper and lower insulating plates.



## Advantages of the Invention

According to the invention, it is possible to obtain a knocking sensor that has good insulation characteristics even at an operating temperature of 150° C. or more and is excellent in the accuracy of knocking detection.

## BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a cross-sectional view of a knocking sensor according to an embodiment of the invention taken along an axial direction.

FIG. **2** is an exploded perspective view of the knocking sensor according to the embodiment of the invention.

FIG. **3** is a view showing an insulation resistance value of the knocking sensor at 150° C.

FIG. **4** is a view showing the surface resistivity of various resins.

FIG. **5** is a cross-sectional view of a knocking sensor in the related art taken along an axial direction.

FIG. **6** is an exploded perspective view of the knocking sensor in the related art.

## EXEMPLARY EMBODIMENTS FOR CARRYING OUT THE INVENTION

An embodiment of the invention will be described below.

FIG. **1** is a cross-sectional view of a knocking sensor **10** according to an embodiment of the invention.

In FIG. **1**, the knocking sensor **10** is a so-called center hole-type non-resonant knocking sensor that has a mounting hole **12*f*,** through which the knocking sensor is mounted on a cylinder block of an internal combustion engine, at the central portion thereof. A sensor body **20** to be described in detail below is covered with a resin molding **11**, so that the knocking sensor **10** is formed. The knocking sensor **10** is formed in the shape of a short cylinder as a whole, and a connector portion **11*b*** protrudes outward from a part of the periphery of the cylindrical knocking sensor in a radial direction. In the connector portion **11*b***, first and second terminals **14*a*** and **16*a***, which extend from lower and upper electrodes **14** and **16**, respectively, protrude (only the first terminal **14*a*** is shown in FIG. **1**) so as to be connected to an external connector (not shown).

Further, as shown in an exploded perspective view of FIG. **2**, the knocking sensor **10** includes a metal shell **12** that is made of metal and includes a cylindrical portion **12*a*** and a flange portion **12*b*** positioned at the lower end of the cylindrical portion **12*a***. An annular lower insulating plate **13**, a lower electrode **14**, a piezoelectric element **15**, an upper electrode **16**, an upper insulating plate **13*t***, a weight **17**, and a disc spring **18** are fitted to the outer periphery of the cylindrical portion **12*a*** in this order from the flange portion **12*b***; and the lower insulating plate **13** is placed on the flange portion **12*b***.

A male screw portion **12*x*** is formed on the upper outer peripheral surface of the cylindrical portion **12*a***. Meanwhile, a female screw portion **19*y*** is formed on the inner surface of a nut **19**. Further, the nut **19** is threadably engaged with the male screw portion **12*x***. Accordingly, a laminated body, which reaches the disc spring **18** from the lower insulating plate **13**, is interposed and fixed between the flange portion **12*b*** and the nut **19**, so that the sensor body **20** is formed. Meanwhile, a cylindrical insulating sleeve **13*s*** is fitted to the outer peripheral surface of the cylindrical portion **12**$a$, so that the lower electrode **14**, the piezoelectric element **15**, and the upper electrode **16** are prevented from being electrically connected to (coming into electrical contact with) the cylindrical portion **12**$a$.

Here, the lower insulating plate **13** is a member that prevents the electrical connection (contact) between the upper surface of the flange portion **12**$b$ of the metal shell **12** and the lower electrode plate **14**, and the upper insulating plate **13**$t$ is a member that prevents the electrical connection (contact) between the upper electrode plate **16** and the weight **17**. The thickness of each of the upper insulating plate **13**$t$ and the lower insulating plate **13** is set to the range of 0.05 mm to 0.50 mm. If this thickness range is satisfied, it is possible to obtain sufficient volume resistance. Accordingly, the upper insulating plate **13**$t$ and the lower insulating plate **13** are made of a general-purpose resin material. In this embodiment, the upper insulating plate **13**$t$ and the lower insulating plate **13** are made of PET (polyethylene terephthalate), and the thickness of each of the upper insulating plate **13**$t$ and the lower insulating plate **13** is 0.35 mm and the volume resistance of each of the upper insulating plate **13**$t$ and the lower insulating plate **13** is 50 GΩ or more.

Meanwhile, in the knocking sensor **10** according to this embodiment, the resin molding **11**, which covers the sensor body **20**, is made of a copolymer (ETFE) of tetrafluoroethylene and ethylene, or polyphenylene sulfide (PPS) excellent in moldability. ETFE is represented by the following formula (1).

$$—(CF_2—CF_2)_m—(CH_2—CH_2)_n \qquad (1)$$

(m and n are natural numbers)

ETFE has moldability (extrusion molding, injection molding, or the like) while having the characteristics of a fluorine resin. ETFE is commercially available as, for example, a fluorine resin ETFE that is manufactured by Asahi Glass Co., Ltd.

PPS or ETFE, which is a resin material forming the resin molding **11**, has a surface resistivity of $1.0\times10^{10}\Omega$ or more at 150° C. and also has a surface resistivity of $1.0\times10^{10}\Omega$ or more at 180° C. (see the following FIG. **4**). For this reason, if the resin molding **11** is made of this material, it is possible to increase the insulation resistance of the knocking sensor **10** as a whole even though each of the upper and lower insulating plates is formed thin so as to have a thickness of 0.50 mm or less and the knocking sensor is exposed to a high temperature of 150° C. or more.

FIG. **3** shows the results of the measurement of the insulation resistance of knocking sensors **10** that include resin moldings **11** made of various resin materials. Meanwhile, an insulating plate, which is made of PET so as to have a thickness of 0.35 mm, an inner diameter of 14.72 mm, and an outer diameter of 23.10 mm, is used as the upper insulating plate **13**$t$ and the upper insulating plate **13**.

First, when a nylon resin (PA**66** of FIG. **3**) in the related art is used for a resin molding, the insulation resistance of the knocking sensor at 150° C. is lower than 10 MΩ. In contrast, when polyphenylene sulfide (PPS of FIG. **3**) of the invention is used as the material of a resin molding, the insulation resistance of the knocking sensor at 150° C. is 10 MΩ or more.

FIG. **4** shows the surface resistivity of various resins. In the case of a nylon resin (PA**66** of FIG. **4**) where the insulation resistance of a knocking sensor is lower than 10 MΩ, the surface resistivity of a resin molding at 150° C. is lower than $1.0\times10^{10}\Omega$. Meanwhile, in the case of polyphenylene sulfide (PPS of FIG. **4**) where the insulation resistance of a knocking sensor is 10 M Ω or more, the surface resistivity of a resin molding at 150° C. is $1.0\times10^{10}\Omega$ or more. Accordingly, it is understood that a knocking sensor can be used at 150° C. or more if a resin molding of which the surface resistivity at 150° C. is $1.0\times10^{10}\Omega$ or more is used.

Meanwhile, even in the case of a copolymer (ETFE of FIG. **4**) of tetrafluoroethylene and ethylene, the surface resistivity of a resin molding is $1.0\times10^{10}\Omega$ or more at 150° C. Accordingly, it is understood that a copolymer of tetrafluoroethylene and ethylene can be used in the invention.

This surface resistivity is obtained according to JIS K6911, and is obtained from a specimen where a bulk body is made of a material of the resin molding **110** and a plurality of annular electrodes is provided on the surface of the bulk body.

Here, the insulation resistance between the metal shell **12** and the upper electrode **16**, the insulation resistance between the metal shell **12** and the lower electrode **14**, the insulation resistance between the upper electrode **16** and the lower electrode **14**, and the insulation resistance between the upper electrode **16** and the weight **17** are measured, respectively; and the lowest resistance value among these insulation resistances is employed as the insulation resistance of the knocking sensor.

The invention is not limited to the above-mentioned embodiment, and it goes without saying that the invention includes various modifications and equivalents included in the spirit and scope of the invention.

For example, a structure where the weight **17** is held by the nut **19**, which is a separate member, with the disc spring **18** interposed between the weight and the nut has been employed in the above-mentioned embodiment. However, the disc spring **18** may be omitted, or one member, which is formed by integrating the weight with the nut, may be used. Further, the nut **19** does not need to be fixed by being threadably engaged with the metal shell **12**, and may be fixed to the upper portion of the metal shell **12** by welding. Furthermore, a structure where the connector portion **11**$b$ is integrated with the resin molding **11** has been employed in the above-mentioned embodiment. However, the connector portion may be separated from the resin molding, the connector portion and the resin molding may be connected to each other by a cable, and the output of the piezoelectric element **15** may be taken from the separated connector portion.

## EXAMPLE

PET having a thickness of 0.35 mm, an inner diameter of 14.72 mm, and an outer diameter of 23.10 mm was used as each of the upper insulating plate **13**$t$ and the lower insulating plate **13**; PZT (lead zirconate titanate) was used as the material of the piezoelectric element **15**; an iron material was used as the material of the weight **17**; an iron material was used as the material of the metal shell **12**; and a nylon resin and polyphenylene sulfide (PPS) respectively were used as the material of the resin molding **11**, so that two knocking sensors **10** were produced.

The insulation resistance value of the obtained knocking sensor **10** at 150° C. was measured. Measurement was performed as follows: the insulation resistance between the metal shell **12** and the upper electrode **16**, the insulation resistance between the metal shell **12** and the lower electrode **14**, the insulation resistance between the upper electrode **16** and the lower electrode **14**, and the insulation resistance between the upper electrode **16** and the weight **17** were measured, respectively; and the lowest resistance value among these insulation resistances was employed as the insulation resistance of the knocking sensor. Meanwhile, insulation resistance (an insulation resistance value) was measured by a megohmmeter WT-8753 (manufactured by HIOKI E. E. Corporation) while a voltage of 500 V was applied between the respective members.

Obtained results are shown in FIG. **3**. When a nylon resin (PA**66** of FIG. **3**) was used as the material of the resin molding as described above, the insulation resistance value of the knocking sensor at 150° C. was lower than 10 MΩ. In contrast, when polyphenylene sulfide (PPS of FIG. **3**) was used as the material of the resin molding, the insulation resistance value of the knocking sensor at 150° C. was 10 MΩ or more. Meanwhile, indicating an upper limit of the measurement of a megohmmeter, the insulation resistance value of the knocking sensor at 50° C. when a nylon resin was used as the material of the resin molding and the insulation resistance values of the knocking sensor at 50° C. and 100° C. when polyphenylene sulfide was used as the material of the resin molding were shown as the upper limit of the measurement of a megohmmeter in FIG. **3**.

It was ascertained that the knocking sensor according to the invention, which uses polyphenylene sulfide as the material of the resin molding as described above, has good insulation characteristics under high temperature.

## EXPLANATION OF REFERENCE

**10**: knocking sensor
**11**: resin molding
**12**: metal shell
**12***a*: cylindrical portion
**12***b*: flange portion
**13**: lower insulating plate
**13***t*: upper insulating plate
**14**: lower electrode
**15**: piezoelectric element
**16**: upper electrode
**17**: weight
**20**: sensor body

The invention claimed is:

**1**. A knocking sensor comprising:

a sensor body that includes:

a metal shell that includes a cylindrical portion and a flange portion positioned at one end of the cylindrical portion and protruding outward in a radial direction;

an annular piezoelectric element that is fitted to an outer periphery of the cylindrical portion;

upper and lower electrode plates that are superimposed on upper and lower surfaces of the piezoelectric element;

a weight that is fitted to the outer periphery of the cylindrical portion so that the piezoelectric element is interposed between the weight and the flange portion;

a lower insulating plate that is disposed between the flange portion and the lower electrode plate and electrically insulates the flange portion from the lower electrode plate; and

an upper insulating plate that is disposed between the upper electrode plate and the weight and electrically insulates the upper electrode plate from the weight; and

a resin molding that is made of a resin and covers the sensor body,

wherein

a thickness of each of the upper and lower insulating plates is in the range of 0.05 mm to 0.50 mm, and

the resin molding is made of polyphenylene sulfide or a copolymer of tetrafluoroethylene and ethylene.

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